Scuola Politecnica e delle Scienze di Base
Università degli Studi di Napoli Federico II

INAF
ISTITUTO NAZIONALE DI ASTROFISICA
NATIONAL INSTITUTE FOR ASTROPHYSICS

INAF - Arcetri

The quadruple image multi-band sensor

A PhD project from a powerful partnership

Status of the project

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Contents

1. Introduction – Phd topic

PhD Research topic

Preliminary project of a **cubesat payload** instrument to detect **exoplanets**, discriminating between planetary transit events and false positive events (the project design starts from the P/L).

Demonstration of feasibility mission/platform

Partnership

Scuola Politecnica e delle Scienze di Base
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Engineering
GNC /Avionics

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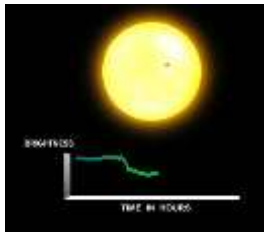
Astronomy
Exoplanets detection

2. Mission objectives

1) Exoplanets Detection --------> **Goal : Earth Like Planets , Sun Like Stars**
Method : Photometric Transit Method



2) False Positive Free --------> **Astronomical False Positives**
Instrumental False Positives

3) Cubesat --------> **Low Cost Project**
Payload dimension and weight constraints (3U)

3. Mission requirements

1) Signal level → **84 ppm (12 ppm noise)**

$$\frac{L_{obs}}{L} = \frac{A_{star} - A_{planet}}{A_{star}}$$

$$1 - \frac{A_{planet}}{A_{star}} = 1 - \left(\frac{R_{planet}}{R_{star}}\right)^2$$

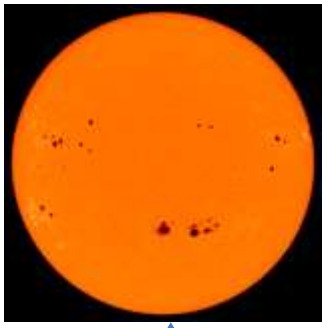
2) Spectral info → **very low spectral resolution in the visible band**
410 nm – 850nm , 3 bands of 150 nm each

3) 3U Cubesat standards → **10 x10x34 , 4 kg , 100Wh (total stored chemical energy)**

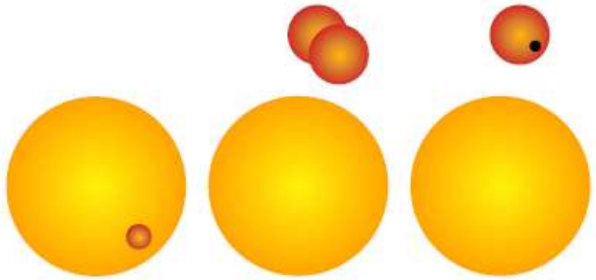
4. The problem of false positive (FP) events

Conditions that mimic the planet transit signal

- Astronomical



Intrisic Stellar Variability



Undiluted eclipsing binary

Background eclipsing binaries/ triple system

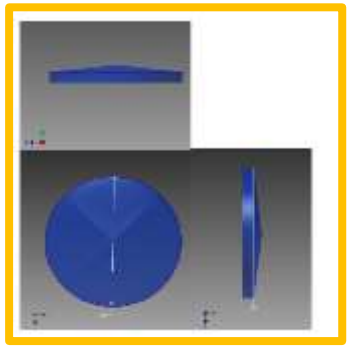
Background transiting planet

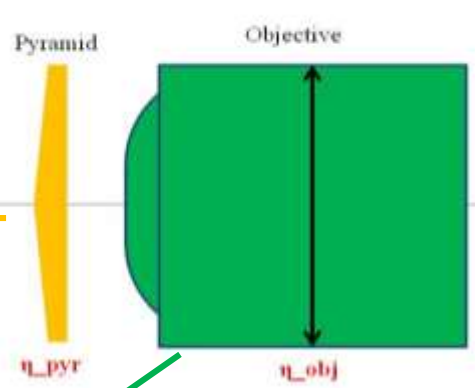
- Instrumental

5. The solution (first attempt)

The quadruple image multi-band sensor

Pyramid

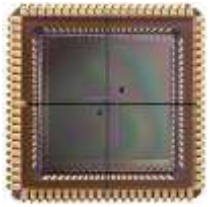




Piezoelectric Stage

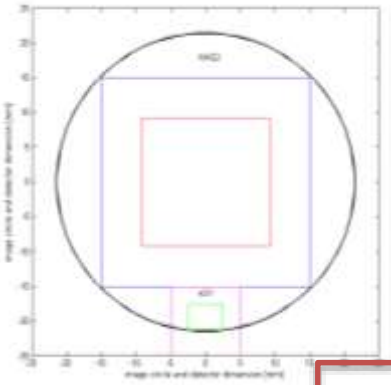
PI P-733.2

ZEISS Planar T 1.4/85
Diameter : 60.7 mm



HAS2:
1024 x1024 pix
Pixel size : 18 µm
FOV : 12.42deg

e2V EV76C454 CMOS

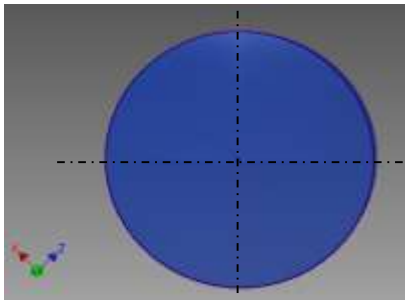


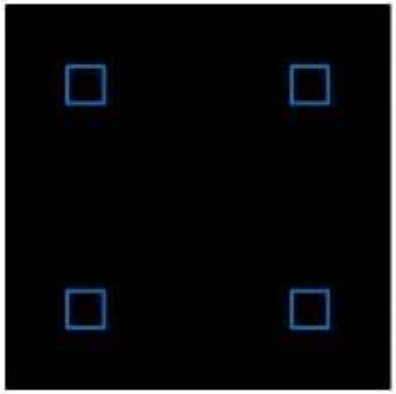
ExoplanetSat –
M. Smith, S. Seager, et alii, *The ExoplanetSat Mission to detect transiting exoplanets with a cubesat space telescope*, Proc. 25th annual AIAA/USU Conference on Small Satellites, 2011.

Travel range x/y: 100 µm
Resolution : 0.1 nm
Pointing precision (simul.): 2.3 arcsec
Residual jitter : 2 ppm

5.1. The pyramid effects

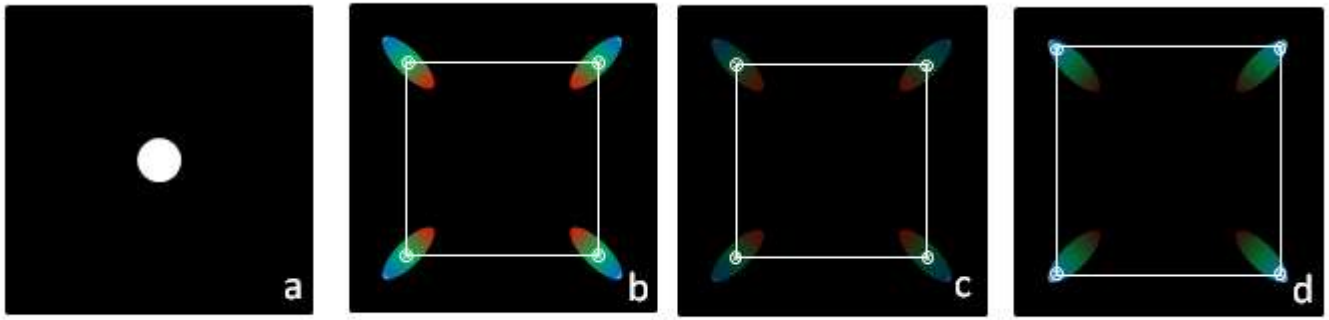
- **4 facets pyramid**
- **4 photometric windows** :
  > redundancy
  > instrumental fake (lower probability)





- **Slightly dispersed images** :
  > spectral information
  > astronomical FP
  > centroid computation in each window
  > shift of the centroid in case of astronomical false positive event

Conceptual
(single spot)

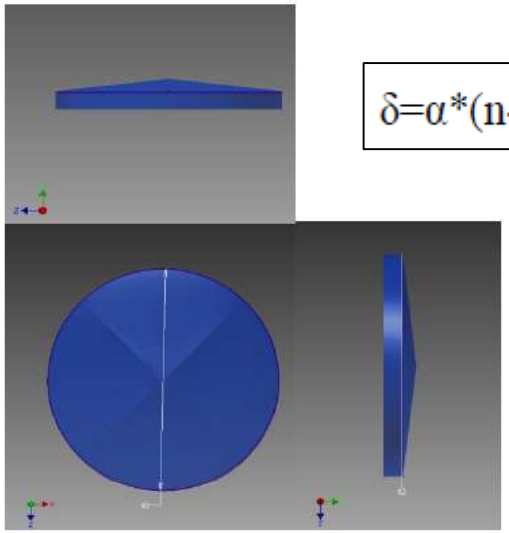


5.2. The pyramid design

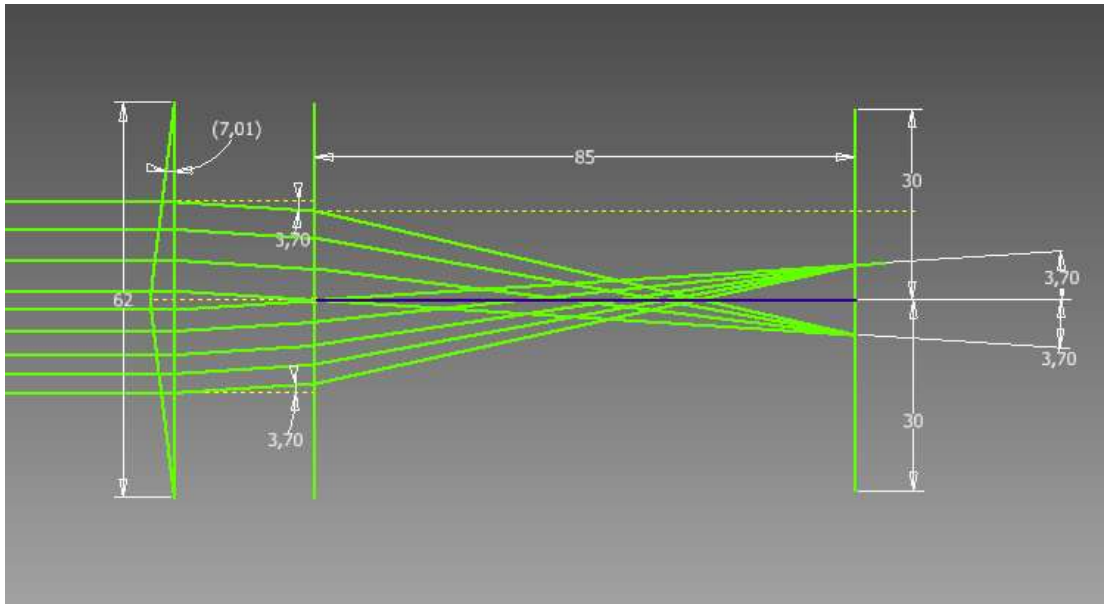
Glass	BK7
Window side size	40-100 pix
Reference refractive index	1.52
windows distance (l)	300 pix
ray deviation (δ)	3.64 deg
Pyramid base angle (α)	7 deg
Wavelength range (3 bands)	410-850 nm
Dispersion	11 pixel (3.5pix/band)

Window size of 40x40 pixels

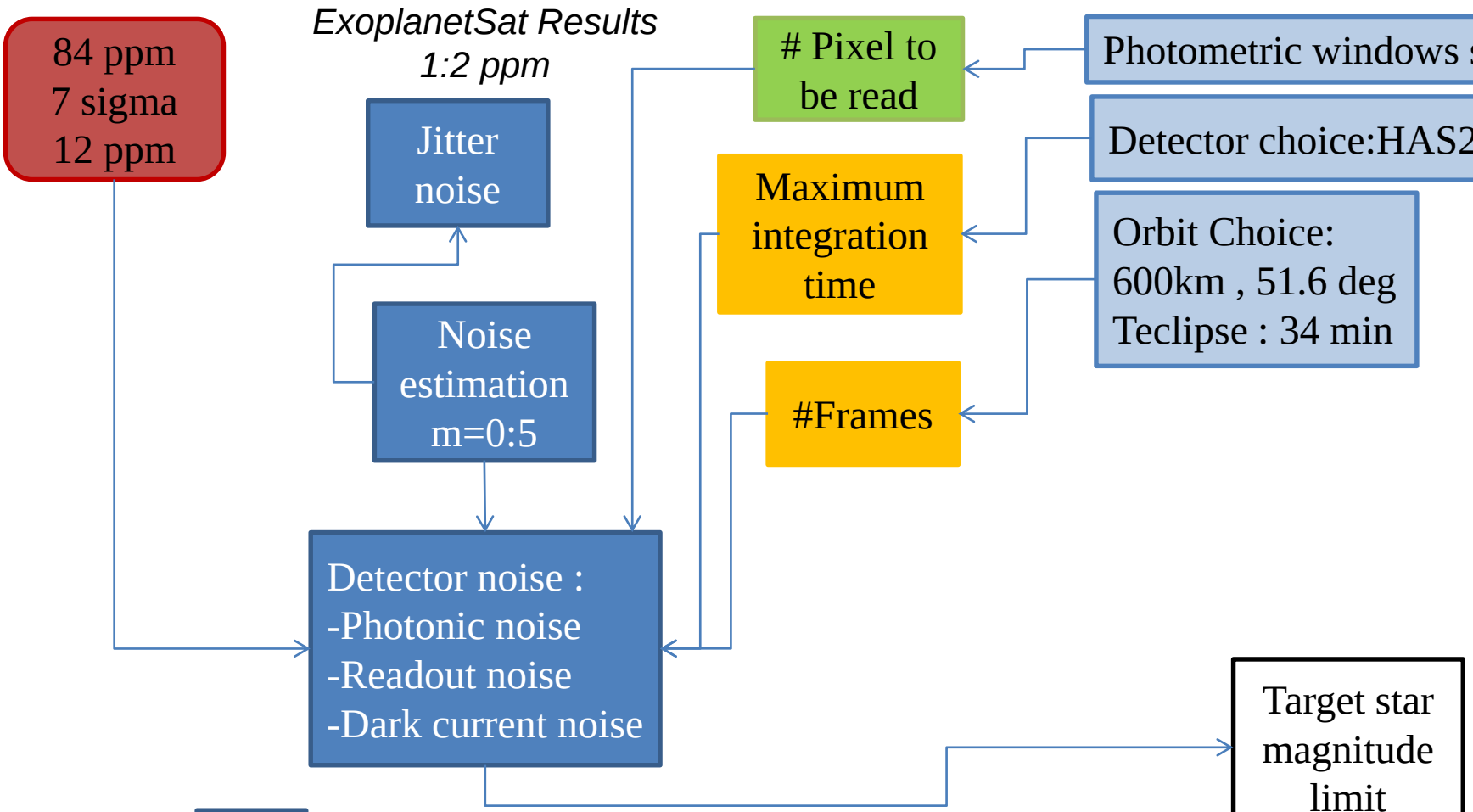
Window:40x40
ADC Resolution: 12 bit
#Frames : 533
Data for 1 orbit : 10 Mbit



$\delta=\alpha*(n-1)$



5.3. The fulfillment of requirement #1



5.4. Maximum integration time

Detector choice:
HAS2

Saturation Voltage
1.49 V

Photons/pix :
2.2*10^5

Star spot defocused on
10x10 pixels

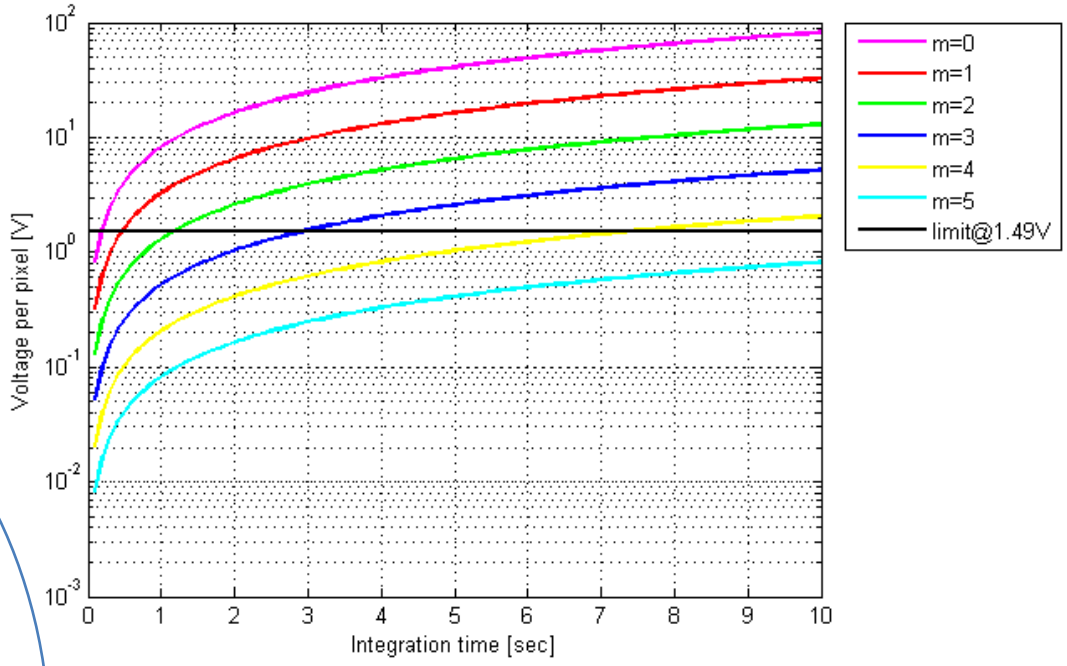
12 ppm maximum noise

S/N =10^5
Phot=10^10 on 10x10 pix
Phot=10^8 per pix

F (coadded frames) : 450

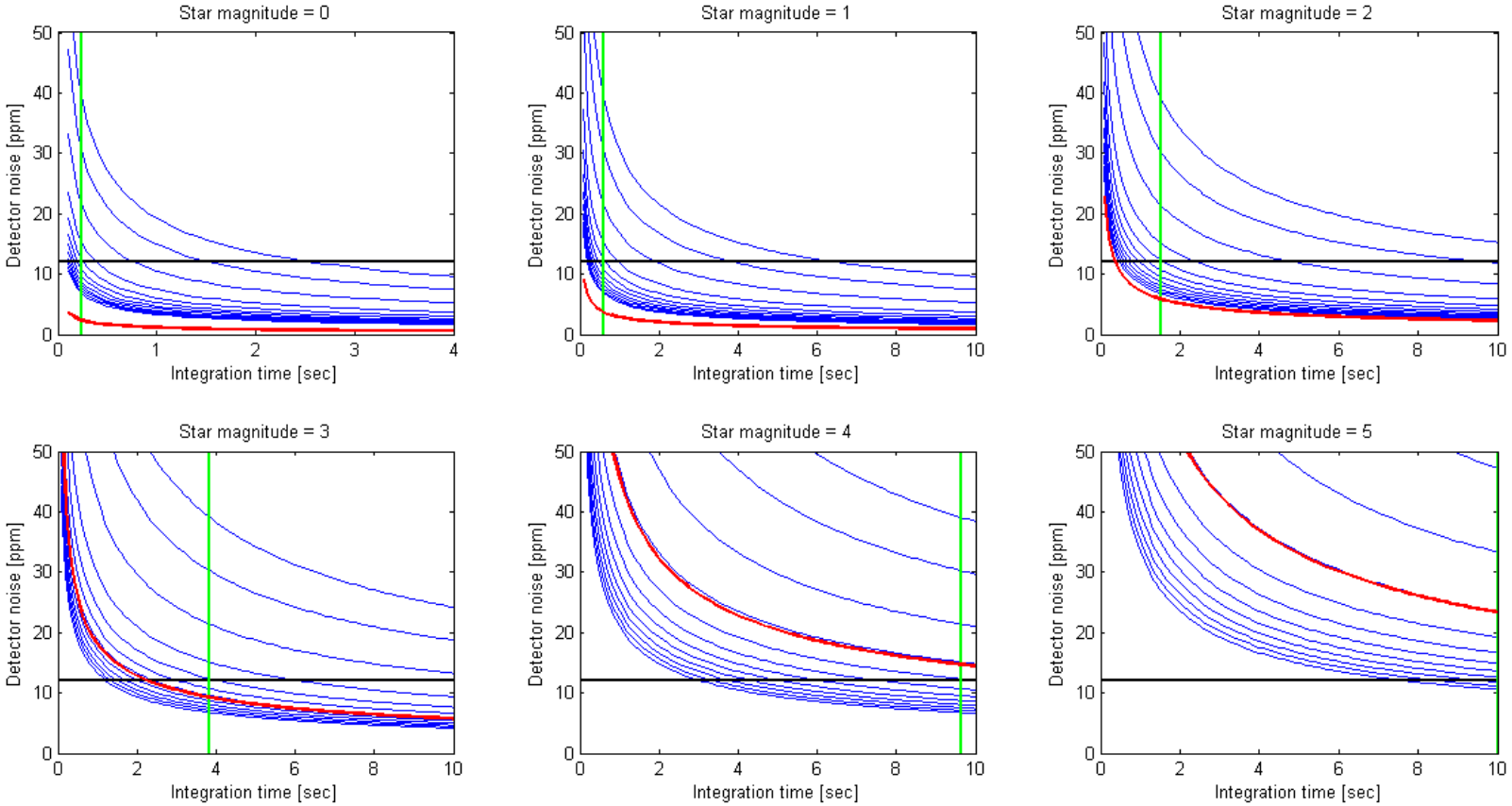
Orbit Choice:
600km , 51.6 deg
Teclipse : 34 min

F lim (t int)



magnitude	integration time limit [s]	F max
0	0.239	8565
1	0.605	3377
2	1.527	1339
3	3.836	533
4	9.643	212
5	10	204

5.5. The star magnitude limit



12 ppm threshold

Maximum frame integration time

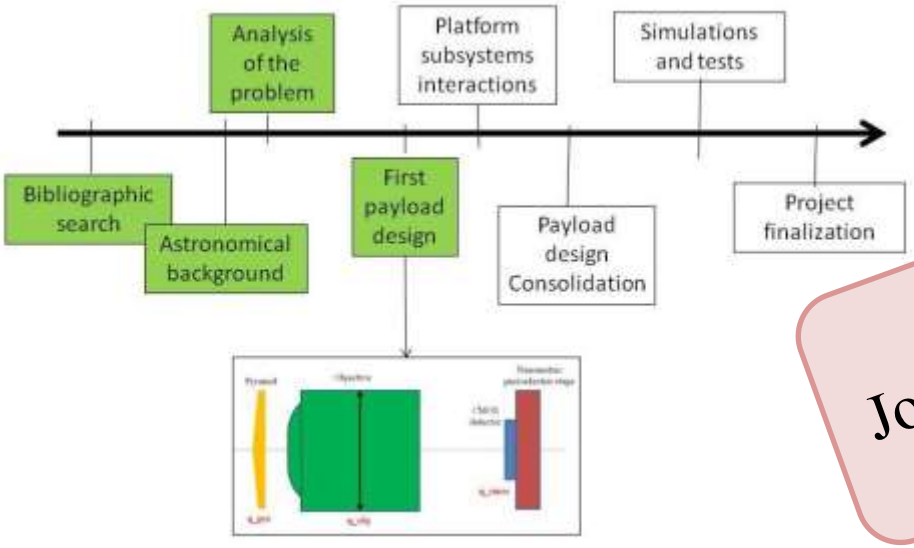
Noise computed with Flim number of coadded frames

6. Conclusion

This short presentation summarizes the estimation of the limit in the target star magnitude in order to reach a noise level of 12 ppm. Stars of magnitude **between 0 and 3** can be theoretically observed.

Complementary observation to large space telescopes.

Next steps :
- Finalization of payload design
- Observation Simulation
- Application to educational opportunities



Join This Project !

Thanks for the attention !!!